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STREAM SURVEYS IN VICINITY OF URANIUM MILLS

I. AREA OF GRAND JUNCTION, COLORADO - AUGUST 1960

PUBLIC HEALTH SERVICE, DENVER, COLORADO

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PB 260 276

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Conference on Pollution of the Interstate Waters
of the Colorado River and Its Tributaries

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16. Abstracts

The results of one of three short-term field studies conducted in the vicinity of uranium processing mills in western Colorado and eastern Utah are presented. The surveys were conducted to determine the pollutional constituents contained in uranium mill discharges and the effect of these discharges on receiving waters in areas of the Colorado River Basin.

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COLORADO RIVER BASIN WATER QUALITY CONTROL PROJECT
Public Health Service

BACKGROUND AND OBJECTIVES

The Colorado River Basin Water Quality Control Project was initiated by the Public Health Service at the request of the water pollution control agencies of the seven Basin states at a conference called by the Surgeon General in Phoenix, Arizona, January 13, 1960, under the provisions of section 8, Public Law 660, 84th Congress, the Federal Water Pollution Control Act. The Project is consequently operating under the interstate enforcement provisions of the Act and is directed toward the accomplishment of the following objectives:

1. A determination of the specific pollutants and their concentrations which now exist or which may reasonably be expected to exist in the immediate future resulting from various water uses within the Basin, and the establishment of priorities for developing data on, and securing needed remedial action at the most critical and pressing problem areas.

2. A determination of methods for securing the best possible water quality for multiple water use and the development of a comprehensive plan and program of water quality control for multiple water use within the Basin which can serve as a guide for the conference and to state and Federal agencies having an interest in the prevention and control of water quality degradation.

Under the conference mechanism the official conferees consist of a representative of the Public Health Service and the water pollution control agencies of each of the states involved. The conferee group associated with this enforcement action is as indicated on the cover of this report.

ORGANIZATION

The Project Headquarters office, consisting of engineering and associated professional and clerical personnel, is located in Denver, Colorado. A laboratory for the sanitary analysis of samples collected has been established in Salt Lake City, Utah, and will provide the facility for radiological, bacteriological, biological, and chemical analyses of the various samples collected.

The Project is administratively attached to the Water Supply and Pollution Control program of the Public Health Service, Department of Health, Education, and Welfare, Region VIII, Denver, Colorado. The Water Supply and Pollution Control programs in DHEW Region VII, Dallas, Texas, and DHEW Region IX, San Francisco, California, are also cooperating with the Project, since portions of these regions lie in the Colorado River Basin.

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For laboratory analyses: C. R. Hirth and M. W. Lammering of the Robert A. Taft Sanitary Engineering Center, and R. K. Jarrell of the Colorado River Basin Project Laboratory.

For assistance and advice in sampling at the Climax Uranium Company Mill: the personnel of Climax Uranium Company.

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For technical consultation: E. C. Tsivoglou of the Robert A. Taft Sanitary Engineering Center and D. E. Rushing of the Colorado River Basin Project Laboratory.

STREAM SURVEYS IN VICINITY OF URANIUM MILLS

I. AREA OF GRAND JUNCTION, COLORADO - AUGUST 1960

by

J. W. Kittrell*
C. E. Sponagle
J. B. Anderson

INTRODUCTION

Purpose

This is a report on one of three short-term field studies carried out in the vicinity of uranium processing mills in western Colorado and eastern Utah during August 1960. These studies were the initial undertaking of the Colorado River Basin Water Quality Control Project. They were conducted for the purpose of determining the pollutional constituents contained in uranium mill discharges and the effects of these discharges on receiving waters in certain specific areas of the Colorado River Basin. Other studies of this nature were carried out in the areas of Uravan, Colorado and Moab, Utah. The results of these studies are reported elsewhere (1)(2).

General Description of Mill Process and Area

The Climax Uranium Company is located in the City of Grand Junction in western Colorado. Both uranium and vanadium are recovered from feed ores. Vanadium is extracted by a salt-roasting, acid precipitation process. Uranium is then removed by an acid-leach, solvent extraction process. A full description of the mill process has been reported elsewhere (3). At the beginning of this survey, the mill had been back in operation only 3 days after a shutdown for employee summer vacations.

All wastes from the mill are discharged into two tailings ponds in series. These wastes include slurries of spent sands and leached slimes, spent vanadium liquor, and vanadium filter cake wash water (3). These ponds lie adjacent to the Colorado River and have a total area of 52 acres. Under normal operation, if the first pond overflows, its discharge goes to the second pond. The combined pond area is sufficiently large to hold all mill liquors so that there should be no direct discharge to the Colorado River under normal operation. At the time of the survey, PHS personnel were informed that the second pond in the series had been used only once in its lifetime of just over 1 year. Both ponds were dry at the beginning of the survey.

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The Colorado River valley beginning just above Grand Junction and continuing to a few miles east of the Colorado-Utah State line is a dry plain, varying in topography from flat to gently rolling. This plain is bounded on the north by the Book Cliffs, on the east by Grand Mesa, on the south by Colorado National Monument, and westward it extends into the desert in eastern Utah. Some crops grown in this area are alfalfa, potatoes, sugar beets, corn, peaches, and onions. Such useful vegetation as there is on the plain is supported largely by irrigation, since the annual precipitation for the entire area ranges from 8 to 10 inches on the average. Beginning southwest of Mack (Figure I), the Colorado River enters more rugged, rocky country, flowing in a series of low-walled, wide canyons to Westwater, Utah, the point farthest downstream on this survey.

Populations of communities in the area and river mileages for those communities which are on the main stem of the river are given in Table I. Certain other pertinent river mileages are also given.

TABLE I
POPULATIONS AND RIVER MILEAGES

Place	Population	Mileage[a]
Climax Uranium Mill	-	1101
Grand Junction, Colorado	18,694	1099-1102
Gunnison River mouth	-	1100
Fruita, Colorado	1,830	1085
Loma, Colorado	100	(b)
American Gilsonite Corporation	-	1079
Mack, Colorado	150	(b)
Colorado-Utah State line	-	1061
Westwater, Utah	2	1056
Little Dolores River mouth	-	1053

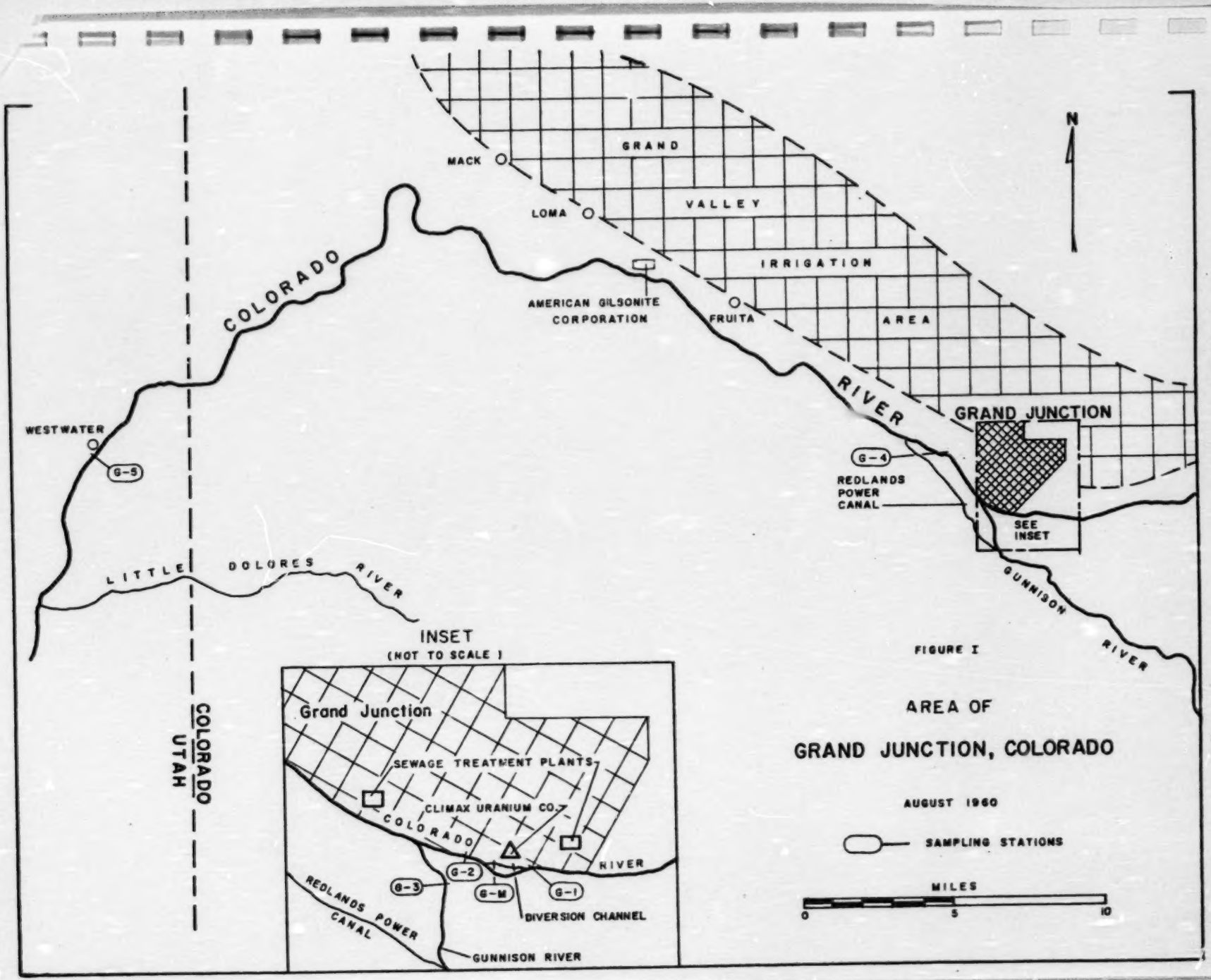
[a]Reference zero mileage is the Arizona-Sonora, Mexico border

[b]Not on main stem of river.

Water Supply

Nearly the entire flow of the Gunnison River was being diverted through the Redlands Power Canal during the survey. This canal leaves the Gunnison River about 2-1/2 miles above its mouth, and it enters the Colorado River about 3 miles below the confluence of the Gunnison and Colorado Rivers (approximate Colorado River mile 1097). A small amount of this water was used for irrigation as well as for the production of power.

At river mile 1122, near Cameo, Colorado, water is taken from the Colorado River for irrigation of the Grand Valley. There are about 70,000 irrigable acres in this development (4). Return flows from the project enter the Colorado River from Grand Junction to Mack via a number of ditches.


GRAND
VALLEY
IRRIGATION
AREA
MACK
LOMA
FRUITA
AMERICAN GILSONITE CORPORATION
COLORADO
RIVER
GRAND JUNCTION
WESTWATER
G-5
G-4
REDLANDS POWER CANAL
SEE INSET
LITTLE DOLORES RIVER
GUNNISON RIVER
COLORADO
UTAH
N
INSET
(NOT TO SCALE)
Grand Junction
SEWAGE TREATMENT PLANTS
CLIMAX URANIUM CO.
COLORADO RIVER
G-3
G-2
G-M
G-1
DIVERSION CHANNEL
REDLANDS POWER CANAL
GUNNISON RIVER
FIGURE I
AREA OF
GRAND JUNCTION, COLORADO
AUGUST 1960
SAMPLING STATIONS
MILES
0
5
10

The Climax Uranium Company takes cooling water for use in the mill process from a channel of the Colorado River created by a low diversion dam.

The domestic water supply of Grand Junction is obtained from Kannah Creek and reservoirs on the Grand Mesa. Water supplies for the small communities in Colorado west of Grand Junction come from springs or wells. Domestic water for Westwater, Utah is hauled in by truck from Harley Dome, Utah, a filling station on U.S. Highway 50. Domestic water for Harley Dome is hauled in from Grand Junction.

The American Gilsonite Corporation downstream from Fruita takes about 1000 gpm from the Colorado for boiler feed water, cooling tower make-up, and drinking water. The boiler feed water is reportedly given complete treatment, including softening, before use. Drinking water comes from a second source as well and is given complete treatment plus chlorination.

During the course of the survey, a number of children were seen swimming in the Colorado River about one-half mile above the mouth of the Gunnison River. The river bottom at this point was covered with a black slime.

Waste Discharge

Sewage from Grand Junction was given secondary treatment in two plants, one upstream from the city, the other downstream, and was discharged to the Colorado River. Floating feces were evident in the stream below the entry points of the effluents from both plants during the period of the survey. It was reported to survey personnel that raw sewage was at times bypassed around the treatment plants. A portion of the Orchard Mesa area just across the river from the center of Grand Junction discharged untreated sewage to the river.

The diversion channel from which Climax Uranium Company cooling water was withdrawn begins slightly downstream from the entry of effluent from one of the Grand Junction sewage treatment plants. Floating feces were also observed in this diversion channel. It was concluded that at least part of the sewage effluent was flowing in this channel.

Raw sewage from Fruita was discharged into Little Salt Wash and carried along with return irrigation flow, in season, into the Colorado River. Sewage disposal in the other communities was by individual family facilities.

CONDUCT OF THE SURVEY

The survey was conducted in the Grand Junction area during the period August 17-28, 1960. Stream and effluent samples were initially processed in the Laboratory of the Grand Junction Water Treatment Plant. Bioassay analyses were performed at the Colorado State Fish Hatchery, Durango, Colorado.

Sampling Stations

The locations of sampling stations are shown in Figure I. A detailed description of the location and features of each station follows in Table II.

TABLE II
DESCRIPTION OF SAMPLING STATIONS

Station	Description
G - 1	Colorado River 0.3 miles upstream from Climax Mill. River bottom rocky, stream velocity moderate.
G - M	Lower end of shallow channel formed by Climax Mill diversion dam. Bottom composed of rocks, slime, and mud, stream velocity moderate.
G - 2	Colorado River below U. S. Highway 50 and D&RGW RR bridges, above mouth of Gunnison River about 1/4 mile. Channel very narrow, rocky bottom, stream velocity high.
G - 3	Gunnison River at bridge below U. S. Atomic Energy Commission Grand Junction Operations Office. Muddy bottom, sluggish flow, about 1 mile above mouth.
G - 4	Colorado River about 1-1/4 road miles below Grand Junction, just above first irrigation return ditch from Grand Valley irrigation. Main channel narrow, rocky bottom, stream velocity high. Several side channels carried small flows.
G - 5	Colorado River about 1/2 mile above Westwater, Utah. River bottom rocky, some mud near shore, stream velocity moderate.

Sample Collection

For sampling purposes, the 12 survey days were divided into two cycles, a 5-day period, August 17-21, and a 7-day period, August 22-28. One quart water samples were taken daily at each station. In addition, at Station G-M, aliquot stream samples were taken daily and composited for each cycle directly into a 1-gallon jug for bioassay studies. These 1-gallon composites were used for bioassay studies without any further field processing. One-pint samples of river sediments were taken once a cycle at each station.

The Colorado River was sampled at Stations G-1, G-2, G-4, and G-5 by wading across the stream and taking a cross-sectional composite of 1-quart. The volume collected at any one point across the stream was roughly proportional to the volume of flow in the river section. At Station G-3, the Gunnison River was sampled from a bridge; equal volumes of water were taken at quarter points across the channel. At Station G-M the Climax Uranium Mill had a monitoring sample pump immersed in the diversion channel of the Colorado River at the downstream corner of the mill property. It was felt that the major portion of any seepage from the mill tailings ponds would probably enter the channel above this point. A portion of the daily sample delivered by the pump was taken for survey purposes.

Because of the rocky bottom and high velocity of the Colorado River in this area, most sediment samples were collected very close to the shore where stream velocities were low enough to allow greater deposition and retention of sediment between the rocks. Sediment samples from the Colorado River bottom consisted of a mixture of mud and organic matter.

Field Processing

All stream and effluent samples were taken to the Grand Junction Water Treatment Plant and filtered through a 0.45 micron pore diameter membrane filter within 2 days after collection. Samples were composited by cycle during filtration.

HYDROLOGY

Flows of the Colorado River in the immediate vicinity of Grand Junction, Stations G-1 and G-2, were measured at the U. S. Highway 50 bridge over the river between these stations. The U. S. Geological Survey furnished a calibration table by which weight-and-wire gage measurements were converted into flows. Staff gages were placed by the Geological Survey in the channels below Grand Junction (G-4) and at Climax Mill (G-M); similar calibration tables were furnished. The total flow of the Gunnison River, as measured by the Geological Survey, is reported, since a fraction of the flow was sampled at Station G-3. Flows at Westwater were considered to be equal to flows measured by the USGS water stage recorder near the State line. No mill effluent streams were observed entering the river. Flow data are presented in Table III.

Comparisons with existing records are possible only at Westwater. No published records of the USGS apply to locations chosen for other sample stations. The comparison at Westwater, however, is very interesting. As seen in Table III, the average flow at Westwater over the survey period was 1285 cfs. Over the period of record for the Colorado River at the State line, May 1951 through September 1959, the average August flow was approximately 3500 cfs. The low average August flow for the period of record was 1514 cfs, occurring during August 1954. Flow during the survey period was considerably less than normal for this time of year.

Flows for the second cycle were higher and generally more variable than for the first cycle. There were light rain showers in the Grand Junction area on August 22 and 24, and there was a heavy thundershower early in the morning of August 23. The Colorado River was muddy at the upstream stations from the 24th through the 27th. At Westwater, the River was muddy from the 25th through the 28th.

TABLE III
FLOWS IN GRAND JUNCTION AREA AUGUST 17-28, 1960 (cfs)

Date	Stations G-1,G-2[a] Colo. River in Grand Junction	Station G-M Climax Mill Diversion Channel	Station G-3[b] Gunnison River at Mouth	Station G-4 Colo. River below Grand Junction	Station G-5 Colorado River, Westwater, Utah
1960					
Aug. 17		34			1190
18	325	28	408	348	1230
19	325	30	429	391	1240
20	325	31	436	391	1240
21	371	33	408	470	1270
22	291	61	394	405	1230
23	295	57	499	338	1330
24	312	88	663	374	1360
25	400	134	645	630	1550
26	450	128	576	740	1730
27	520	132	536	860[c]	1740
28	485	124	471	764	1670
Survey average	373	73	497	519	1397
Cycle I average	336	31	420	400	1234
Cycle II average	393	103	541	587	1518

(a) Measured at bridge, U. S. Highway 50
(b) This column gives the total flow of the Gunnison River, for which samples were taken at Station G-3
(c) Estimated

RESULTS AND DISCUSSION

Biological

Method

Composite samples from Climax Mill Diversion Channel were taken to the State fish hatchery at Durango, Colorado for bioassay analysis. Facilities were available there to subject rainbow trout to various dilutions of the samples under constant temperature. Containers with 2 liters of test solution were placed in hatchery troughs which contained spring water at a temperature of 52°F. Water from the Animas River at the fish hatchery was used for dilution purposes. The fish were exposed to the test solutions for 72 hours, and the number surviving this exposure period was counted. Control tests of fish in dilution water only were run for each test series.

Chemical tests for alkalinity, hardness, dissolved oxygen, and pH were performed on many of the test solutions. These analyses were done on unfiltered samples, in contrast to those reported in the next section on chemical results. Dissolved oxygen determinations were made at the start of tests and whenever there was reason to believe that the concentrations had lowered to endanger survival. Sufficient oxygen was maintained by limiting the number of fish in a container.

Results

Results are presented in Table IV and indicate that the combination of tailings seepage, sewage treatment plant effluent, and river water in the mill diversion channel during this survey was not toxic to the test fish. Since only a small number of fish were involved in the tests, these results should be viewed only as indicative of toxicity effects. More complete test work is necessary for a firmer basis of interpretation.

TABLE IV
BIOASSAY RESULTS, CLIMAX MILL DIVERSION CHANNEL SAMPLES

Sample	% Waste	% Survival 72 hr.	pH	Alkalinity mg/l as $CaCO_3$	Hardness mg/l as $CaCO_3$	D.O. mg/l	No. of fish
Cycle I	18	100	7.6	188	300	6.2	2
Composite	32	100	-	-	-	-	2
	56	100	7.6	156	455	5.8	2
Cycle II							
Composite	56	100	7.5	-	415	-	2
	100	100	7.3	-	560	-	2

Chemical

Chemical analyses were performed at the Field Operations Section Laboratory, Robert A. Taft Sanitary Engineering Center, and are presented in Table V.

In general, these data show that, in terms of the analyses performed, the mill was contributing a small amount of chemical pollution to the river. In surveying the information, it may be recalled that Station G-M reflects the immediate effect of seepage from the tailings ponds into the river. Station G-1 in indicative of the condition of the river above the mill, Station G-2 is reflective of the condition of the river below the mill but above the confluence with the Gunnison, Station G-4 takes into account mainstem conditions before irrigation return flows enter below Grand Junction, and Station G-5 presents the quality of the Colorado River as it leaves the Grand Junction area.

The mill diversion channel sample had a pH somewhat lower than the Colorado River above Grand Junction. This was most likely caused by seepage from the mill lagoons and apparently modified the stream pH slightly for some miles downstream. Alkalinity at all stations was present largely in bicarbonate form. No calcium or magnesium determinations were made on either stream or diversion channel samples. In view of this, no direct conclusions can be drawn as to the nature of the salts which combined to make the hardness (525 to 850 mg/l) found in the survey area. It appears, however, that sulfate salts of calcium and magnesium would be primary contributors to hardness and that similar bicarbonate salts would be lesser contributors.

The vanadium analyses indicate that some vanadium was seeping from the tailings ponds into the river.

During the survey the Gunnison River flow was divided into two parts a short distance above its mouth. A very small part of the flow continued down the natural channel and was sampled at the mouth. Most of the flow was being diverted through the Redlands Power Canal and reentered the Colorado River downstream from Grand Junction, about 2 miles below Station G-4. It was felt that water in both channels was essentially of the same quality, so only one sample was taken to represent both flows. The Gunnison River is highly mineralized during low flows from the Black Canyon of the Gunnison National Monument to its mouth, reportedly due to natural accretions and return irrigation flows (5). These causes may contribute to the high sulfate content noted near the mouth of the Gunnison River (an arithmetic average of 955 mg/l over the survey period as compared to 540 mg/l in the Colorado River just above the mouth of the Gunnison). Over the survey period, arithmetic averages of sulfate and hardness at Westwater were 890 and 849 mg/l respectively. These are notably higher than the corresponding averages at the sampling point on the Colorado River just below Grand Junction, 525 and 585 mg/l, respectively. Entry of the main flow of the Gunnison River through Redlands Power Canal between the sampling point just below Grand Junction and Westwater accounted for part of the noted increase. Another part of this increase may be due to return flows from Grand Valley irrigation. Sulfate concentrations at all survey stations were in excess of limits recommended in the U. S. Public Health Service Drinking Water Standards (6).

TABLE V
CHEMICAL RESULTS in mg/l[a]

Analysis	Cycle	G - 1 Colo. R. above mill	G - M Mill diversion channel	G - 2 Colo. R. below mill	G - 3 Gunnison River	G - 4 Colo. R. below Grand Jct.	G - 5 Colo. River, Westwater
pH	I	7.7	5.5	7.8	7.8	7.2	7.8
	II	8.0	6.4	7.3	7.9	7.2	8.0
Alkalinity as $CaCO_3$	I	162.	14.	156.	150.	146.	154.
	II	160.	58.	126.	150.	136.	162.
Hardness as $CaCO_3$	I	566.	707.	632.	821.	604.	849.
	II	528.	670.	547.	849.	566.	849.
Mn	I	<0.15	0.62	<0.15	0.36	0.20	<0.15
	II	<0.15	0.40	<0.15	<0.15	0.15	0.15
Fe	I	0.08	0.36	0.08	0.12	0.11	0.08
	II	0.10	0.41	0.09	0.08	0.08	0.12
As	I	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	II	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Se	I	0.002	0.014	<0.001	0.004	0.007	0.001
	II	<0.001	<0.001	0.005	<0.001	0.002	<0.001
V	I	<0.005	0.76	0.07	<0.005	0.025	<0.005
	II	<0.005	0.24	0.025	<0.005	0.035	<0.005
Cu	I	0.011	0.073	0.010	0.017	0.007	0.003
	II	<0.002	0.026	0.007	0.003	0.005	0.018
Na	I	244.	400.	322.	248.	284.	-
	II	300.	330.	258.	270.	284.	-
F	I	0.62	1.2	0.49	0.82	0.55	0.57
	II	0.45	0.78	0.68	0.80	-	0.65
Cl	I	110.	160.	110.	13.	120.	85.
	II	110.	140.	120.	13.	110.	86.
NO_3asN	I	1.86	11.6	2.00	0.80	2.28	1.54
	II	1.66	10.9	3.04	0.98	2.46	1.50
SO_4	I	490.	710.	520.	910.	530.	900.
	II	450.	620.	560.	1000.	520.	880.
Total Dissolved Solids	I	-	-	1340.	1700.	1380.	-
	II	-	-	-	-	-	-

[a] Except pH

Table VI lists the weights of several chemical constituents calculated to have passed sampling points during the survey. With reference to Tables V and VI, little, if any, sodium, chloride, or sulfate are contributed by the uranium mill on the basis of average differences between Stations G-1 and G-2. During the survey, the average increase in sulfate between Grand Junction (G-2) and Westwater was 5,524,000 lb/day. Of this increase, 2,487,000 lb/day or 45 percent of the total came from the Gunnison River through its natural channel and the Redlands Power Canal. The remaining 55 percent, or 3,037,000 lb/day may have come largely from return irrigation flows from Grand Valley.

TABLE VI
CALCULATED WEIGHTS OF SODIUM, CHLORIDE, AND SULFATE PASSING SAMPLE POINTS (1000 lb/day)

Station	Description	Cycle	Na	Cl	SO_4
G-1	Colo. R. above mill	I	438	200	889
		II	636	233	953
G-M	Mill Diversion Channel	I	67	27	118
		II	183	78	344
G-2	Colo. R. below mill	I	583	199	942
		II	548	254	1190
G-3[(a)]	Gunnison River	I	561	29.4	2065
		II	787	37.9	2910
G-4	Colo. R. below Grand Junction	I	613	259	1140
		II	899	348	1640
G-5	Colo. R., Westwater	I	-	565	5980
		II	-	703	7200

[(a)] These figures represent the total contribution of the Gunnison River as sampled at Station G-3.

In the mill diversion channel, concentrations of iron, manganese, and nitrate, (as N) averaged 0.38, 0.51, and 11.3 mg/l respectively. Enough dilution water in the Colorado River was available so that the concentrations dropped to 0.09, <0.15, and 2.5 mg/l respectively at Station G-2, about one-half mile below the mill. These values are below recommended limits in the U. S. Public Health Service Drinking Water Standards (6), with the possible exception of manganese.

Radiological

Radiological analyses are presented in Table VII. Most of the radium-226 analyses were performed by a private laboratory; the remaining radium-226

TABLE VII

RADIOLOGICAL ANALYSES, GRAND JUNCTION AREA, AUGUST 1960

Station	Description	Water Samples				Sediment Samples[a]					
		Cycle I		Cycle II		Cycle I			Cycle II		
		Dis. Radium-226 μμg/l	Dis. Uranium μg/l	Dis. Radium-226 μμg/l	Dis. Uranium μg/l	Gross α μμc/g	Gross β μμc/g	Radium-226 μμg/g	Gross α μμc/g	Gross β μμc/g	Radium-226 μμg/g
G-1	Colo. R. above mill	0.3	12.	1.6	14.	15.	40.	3.2	26.	59.	3.4
G-M	Mill Diversion Channel	3.9	-	4.8	35.	380.	480.	13.	660.	620.	19.
G-2	Colo. R. below mill	1.1	22.	1.5	21.	250.	510.	3.7	340.	550.	4.8
G-3	Gunnison River	0.2	20.	<1.	19.	11.	24.	<1.	8.4	33.	<1.
G-4	Colo. R. below Grand Junction	0.7	17.	0.9	17.	25.	44.	1.4	99.	270.	2.9
G-5	Colo. R.,Westwater	0.3	17.	<1.	17.	21.	45.	2.1	15.	52.	2.0

[a] All analyses are in μμc or μμg/gm of dry sediment.

and all of the uranium analyses were done by Colorado River Project Laboratory personnel at the Public Health Service Occupational Health Field Station, Salt Lake City, Utah. Gross radioactivity analyses were carried out by personnel of the Field Operations Section Laboratory, Robert A. Taft Sanitary Engineering Center, Cincinnati, Ohio. In general, the data are consistent within any given cycle and in order of progression downstream.

Dissolved radium-226 values at the six stations sampled range from less than one to 4.8 μμg/l. All water samples for which definite results were reported contained higher dissolved radium-226 concentrations during Cycle II than during Cycle I. For stations G-M, G-2, and G-4, all in the immediate area of Grand Junction, the ratio of dissolved radium-226, Cycle II, to dissolved radium-226, Cycle I, ranges from 1.25:1 to 1.35:1. During a part of the second cycle, the Colorado River in the immediate vicinity of Grand Junction was extremely turbid. Later in the cycle, as stream flow increased at Westwater, turbidity also increased. There was a period of rain around and upstream of Grand Junction August 22nd and 24th, with a heavy storm on August 23rd. The increase in stream flows resulting from this rain may be seen in the data of Table III.

Some of the turbidity noted at the sampling stations probably came from resuspension of previously settled radium-bearing solids originating upstream. As these solids were brought into more intimate contact with the river water, it is possible that some of the radium-226 associated with these solids was more readily dissolved, thus giving the noted higher values. All stations on the Colorado River in the immediate area of Grand Junction had higher concentrations of gross alpha radioactivity in sediment samples of Cycle II than in the corresponding samples of Cycle I. The ratio of gross alpha radioactivity in sediment, Cycle II, to gross alpha radioactivity in sediment, Cycle I, ranged from 1.4:1 to 4.0:1 for the four stations just mentioned. This also suggests the possibility of redistribution of radioactivity-bearing sediment along the stream bed with the occurrence of enough rain to cause conditions of high stream turbidity. Such effects are similar to those demonstrated in earlier studies of the Animas River (10).

Handbook 69 of the National Bureau of Standards (7) gives maximum 168-hour occupational exposure limits to radium-226 and uranium in water as 10^{-7} μc/cc and 2×10^{-4} μc/cc respectively. The International Commission on Radiological Protection (8) recommends a maximum of 1/30 of the continuous occupational exposure, or 3.3 μμg/l for radium-226 and 20,000 μg/l for uranium, for lifetime consumption by the general population. In the U. S. Public Health Service Drinking Water Standards, an annual average concentration of greater than 3.0 μμg/l of dissolved radium-226 in water is grounds for rejection of the source as a supply of drinking water. Dissolved radium-226 levels in the mill diversion channel were slightly above this level during the survey. This suggests that the radium-226 level in the seepage was somewhat higher still. Dissolved uranium levels were considerably below 20,000 μg/l at all survey stations. Dissolved radium-226 concentrations above Grand Junction, at the mouth of the Gunnison, just below Grand Junction, and at Westwater all averaged less than one μμg/l. Concentrations of less than one μμg/l of

radium-226 occur generally in surface waters of the Colorado River Basin above sources of radioactive contamination.

Based on radium-226 and uranium analyses for Stations G-1 and G-M and the corresponding flows as given in Table III, the amounts in Table VIII are calculated as entering the Colorado River between these two stations. These figures represent an estimate of the uranium and radium-226 inflows by seepage from the mill tailings ponds.

TABLE VIII
ESTIMATED AVERAGE CONTRIBUTIONS TO COLORADO RIVER
OF RADIUM AND URANIUM FROM CLIMAX MILL

	Ra-226, mg/day	U,g/day
August 17-21 - Cycle I	0.27	-
August 22-28 - Cycle II	0.81	5320

Table IX presents data on radioactivity in sediments from sampling points located upstream of known sources of contamination (9). These data indicate generally the level of radioactivity to be found in naturally occurring Upper Colorado River Basin sediments. With the exception of the station at the mouth of the Gunnison, the radium-226 concentrations in the sediment samples are slightly higher than the usual natural level, about 1.3 μμg radium-226/gram sediment. The gross alpha results in the mill diversion channel, just below the mill on the Colorado River, and just below Grand Junction are much higher than the corresponding radium analyses, indicating that these alpha levels probably have uranium as their major constituent.

TABLE IX
BACKGROUND LEVELS OF RADIOACTIVITY IN RIVER SEDIMENTS[a]

Location	Gross α μμc/gm	Gross β μμc/gm	Radium-226 μμg/gm
Colorado River at Silt, Colorado	6.5	78.	1.7
Yampa River at Juniper Springs, Colo.	4.0	50.	<1.0
Green River near Dutch John, Utah	8.6	45.	<1.0
San Juan River above Farmington, N.M.	5.3	21.	0.9
Animas River above Durango, Colo.	11.	29.	1.3
Dolores River above Slick Rock, Colo.	14.	43.	2.2
San Miguel River above Naturita, Colo.	9.5	38..	1.0
Tomichi Creek above Gunnison, Colo.	11.	47.	1.2
Gunnison River above Tomichi Creek	9.0	52.	1.6

[a] All analyses are in μμc or μμg/gm of dry sediment.

The results from sediment samples at Station G-1 (Table VII) indicate a slightly higher level of radioactivity than the background values shown. This is most probably due to a source of radioactive contamination upstream from Grand Junction. There is no know direct discharge to the Gunnison River system from the uranium mill at Gunnison, Colorado; the radioactivity levels at Station G-3 on the Gunnison River are comparable to background as shown in Table IX.

Progressing downstream from the mill, the weight of radium-226 in sediment generally declines while the ratio of radium-226 to gross alpha activity increases. In background samples, the ratio of radium-226 to gross alpha activity ranges from 0.1 to 0.26 with most values from 0.1 to 0.2. These ratios range from 0.014 in the Colorado River just below the mill and 0.03 in the mill diversion channel to 0.1 in the Gunnison River and in the Colorado River at Westwater.

SUMMARY

A stream survey was carried out in the vicinity of Grand Junction, Colorado during the period August 17-28, 1960, directed primarily to the investigation of the effects of uranium mill operations on the Colorado River. Water and sediment samples were collected at six sampling stations, involving both the Colorado and Gunnison Rivers, from above Grand Junction, Colorado, to Westwater, Utah a distance of some 46 miles.

From Grand Junction to Westwater, there was a large increase in the concentrations of sodium and sulfate in the Colorado River. A large increase in sulfate concentration came from the inflow of the Gunnison River. Another large increase is strongly indicated as resulting from return irrigation flows. The Climax Uranium Company mill was contributing a small amount of chemical pollution to the river in terms of the analyses performed. Measured concentrations of most chemical constituents were within limits recommended in the 1961 U. S. Public Health Service Drinking Water Standards. Sulfate and total dissolved solids values were above these limits for all analyses performed.

Levels of radium-226 were below the limits in the Drinking Water Standards for all stations surveyed except the mill diversion channel. Dissolved radium-226 concentrations increased in the river during a period of rain; this may be primarily attributed to dissolution of radium-226 associated with a redistribution of river sediments. Concentrations of radium-226 in river sediments were generally higher than those of sediments above known sources of radioactive contamination. Levels of dissolved uranium were very low at all survey stations.

There was no apparent toxicity to fish from the sampled combination of tailings seepage and river water found in the mill diversion channel. Further work is necessary to define this more firmly, due to the small number of fish used in these tests.

It is noted again that the mill had been in operation for only a short period of time when this survey was made and there was no approach to a normal liquid level in the tailings pond during the time of the survey. It

is therefore recommended that another survey of this area be carried out at such a time when the effects of more normal mill operation, particularly with respect to the effect of increased head in the tailings pond on seepage rate, may be investigated.

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